1. What is "Reconditioning" – And is it necessary?

"Reconditioning" is a process that determines the battery capacity and impedance on a regular basis, to obtain an accurate SOC reading even as the battery ages.

RRC smart batteries automatically perform the reconditioning process via their fuel gauge.
For most applications, additional knowledge of the process is unnecessary.

There is one exception.

Certain battery usage patterns may prevent the automatic reconditioning process from occurring.
Only if the "remaining runtime" reading is safety-relevant, it may be necessary to manually initiate the reconditioning process by following the procedure outlined below.

2. General background

If no current flows, the fuel gauge in a smart battery always precisely determines the relative SOC (in %). However, the reading of the absolute SOC (in Ah) may become incorrect as the available battery capacity slowly decreases over time due to

- decay processes (of the electrolyte and the electrode) and
- deposits (lithium builds a permanent compound with the electrodes, called lithium plating).

For the same reasons, the internal battery impedance slowly increases over time, which can cause an imperfect estimation of the SOC (in %) during high current flow.

Reconditioning lets the fuel gauge "re-learn" the total capacity and battery impedance. After reconditioning, the SOC reading is accurate again.

3. The Role of MaxError()

MaxError() is a register that indicates how much the SOC reading can deviate from reality. Because the fuel gauge cannot directly measure the decay processes and deposits, it assumes a worst-case scenario and increments the MaxError() register

- By 0.05% per day.
- By 0.05% per discharge cycle.[1]

Let's take an example:

Assume that you've used the battery for 30 days (= 30x 0.05% = 1.5%) and you've done 10 full discharge cycles during this period (= 10x 0.05% = 0.5%). Knowing that the MaxError() register initializes at 1%, MaxError() adds up to 1%+1.5%+0.5% = 3%.

This means that the SOC would have a maximum uncertainty of ±3%. For a SOC of 80%, the "real" SOC could be in-between 77% and 83%.

Please note:

- If the discharge current is low, the SOC tends to be very exact. The possible error is higher on high discharge currents but should not exceed MaxError().
- In experiments, the actual deviation we measured was mostly below 1/6 of the MaxError() value. In our example, it would be more realistic to assume a SOC deviation of ±0.5 to ±1% instead of ±3%.

After reconditioning, MaxError() resets to 1%.

Note: There are two exceptions to the statements in this chapter:

1. *The RRC1130 does not have a MaxError() register,*
   but the conditioning cycle still works in the way it is explained in the following section.
2. *The MaxError() register in the RRC3570 battery does not initialize to 1%, but to 2%.*

[1] A discharge cycle is defined as 90% outtake of the full charge capacity. This is cumulative: If you discharge 9 times 10% (and recharge in-between), it also corresponds to 90% or one cycle.

4. Recondition cycle

4.1. When is it necessary to perform a recondition cycle?

As you can see below, the necessary steps for reconditioning a battery may "accidentally" happen during normal battery usage. Consequently, many applications do not require reconditioning for a long time or not at all.

Also, most applications do not depend on SOC accuracy. If that's your case, you can safely ignore MaxError() and do not need to care about reconditioning.

However, suppose it is crucial for your application to have an accurate SOC reading. In that case, you should recondition the battery after the MaxError() reading surpasses a certain threshold that you may freely choose based on your needs on accuracy.

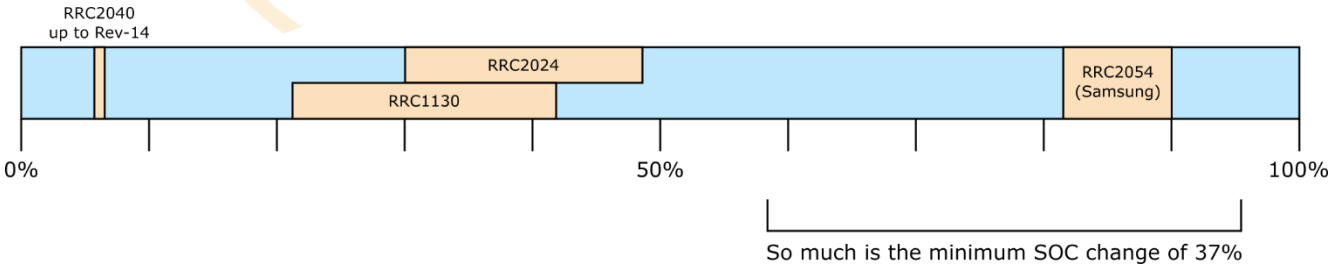
You can implement a recondition algorithm within your application. Or you can use either the RRC-SMB-UBC or the RRC-SMB-DBC charger.[2] Both chargers automatically start a reconditioning cycle upon inserting a battery showing the CF flag, which is set by the fuel gauge if MaxError() ≥ 5%.

4.2. Reconditioning RRC11xx and RRC2xxx batteries

These are the necessary steps for reconditioning a battery:

1. Let the battery rest at an ambient temperature between 10°C and 40°C (50/104°F).
   Allow the battery to enter a well-relaxed state. A recondition measurement happens when all cell voltages are stable enough (i.e., the voltage change is slower than 4 µV/s). That typically happens after 1 h at a SOC of 0 to 80% or after 4 hours at a SOC above 80%. It takes longer at lower temperatures. The measurement is taken at the latest after 5 hours.
2. Continuously charge or discharge the battery to change the SOC by at least 37%.
   The current should always be >30 mA, and it should be >150 mA on average.
   Charge and discharge currents up to C/3 are possible if the battery temperature stays between 10°C and 40°C.[3]
3. Let the battery rest again under the same conditions as in step 1.
   If the SOC is below 10%, you do not need to wait: the recondition measurement happens immediately.[4]

Restrictions: Depending on the battery type, some SOC regions do not allow a recondition measurement. A recondition measurement will have no effect if the SOC is within the regions that are drawn in soft read in the following graph:



[2] Works only with RRC20xx batteries.

[3] The battery charge/discharge rate is typically given in „C", which is the electrical current in relation to the battery capacity. For example, for a battery with a capacity of 9 Ah, 1 C corresponds to a current of 9 A, and C/3 would correspond to 3 A.

[4] For the RRC2020, RRC2024 and RRC2040, the "fast recondition measurement" only works starting from battery revision 9.

Those restricted areas may change from one battery generation to the next. If you want to implement a reconditioning cycle and want it to work over several battery generations, ensure to let the battery dwell at 100% and 60% SOC. This way, you fulfill the requirement of having a change in SOC of 37%, and it is most likely that the battery makes a reconditioning measurement outside the restricted areas.

4.3. Reconditioning the RRC3570 battery

These are the necessary steps for reconditioning an RRC3570 battery. The battery temperature must stay above 10°C / 50°F during the whole reconditioning cycle.

1. Charge the battery to 100%.
2. Discharge the battery to ≤ 5%.
   The current should always be >30 mA, and it should be >150 mA on average. There is no upper current limit.
3. Once the battery is discharged, the reconditioning measurement takes place. There is no waiting time. You can immediately recharge your battery in preparation for the next use.

5. Revision History

Revision	Valid from	Changes	Author
A	07. Feb 2022	First release of this Application Note.	Bernhard Krämer
B	20. Oct 2022	Rewritten for more clarity. Added information on reconditioning RRC11xx and RRC3570 batteries.	Bernhard Krämer

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